Strain and Strain Rate Imaging
How, Why and When?

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Disclosures: No conflicts of interest
Movement vs Deformation
Doppler Myocardial Velocities

Color DTI

Pulsed DTI
Tissue Velocity Imaging cannot Discriminate between Actively Contracting Muscle and Muscle that is moving because of Tethering
Normal Strain and Torsion

Counter-clockwise

Rotation as viewed from apex

Clockwise

Contraction

Systole

Diastole

Apical

Basal

Time

Strain = deformation

• Strain is defined as the deformation of an object, normalized to its original shape.

• Strain Rate (SR) should be understood as the rate of myocardial deformation over a period of time.

• Strain Rate (SR) = \( \frac{\text{Strain}}{\text{time}} \)
Strain Calculation

- Strain ($\epsilon$) = $\frac{L-L_0}{L_0}$

- Strain ($\epsilon$) = $\frac{7-9}{9}$
Strain Calculation from Tissue Velocities

Strain tracking
Strain Rate Calculation

- Distance is calculated by velocity, i.e.: Distance = Velocity x Time
- If $V_1 > V_2$, SR is **negative** and there is **shortening**
- If $V_2 > V_1$, SR is **positive**, indicating **lengthening**
- If $V_1 = V_2$, SR is **zero**, no shortening nor lengthening.

\[ SR = \frac{v_2 - v_1}{d} \]
Directions of Cardiac Strain

- Longitudinal
- Radial
- Circumferential
Caveats of TD derived Strain

- Doppler angle-dependent
- The comparison of adjacent velocities is exquisitely sensitive to signal noise ratio.
- High frame rates needed. (lower spatial resolution).
Is it possible to derive strain directly from the B-mode image??
Not a New Idea, Just Better Implementation

LOCAL MYOCARDIAL DEFORMATION COMPUTED FROM SPECKLE MOTION

Jean Meunier, Michel Bertrand, Guy E. Mailloux and Robert Petitclerc

Ecole Polytechnique, C.P. 6079, Station "A"
and Institut de Cardiologie, 5000 Belanger E.,
Montreal, H1T 1C8, CANADA

Fig. 2 A typical echocardiographic image (short axis view) and two successive frame ROI after lowpass filtering near end-diastole.

Fig. 3 Velocity (motion) vector fields computed from the two ROI in fig. 2 near end-diastole. The composite (C), translational (T), rotational (R) and deformation (D) fields are represented. The coordinate origin is the ROI center.
Derivation of 2D Strain by Echo

Leitman M et al. JASE 2004; 17:1021-29
How to Obtain and Analyze 2D Strain in Practice
Image Acquisition
Longitudinal Strain

• Apical views: 4, 2, 3 chamber on axis, non foreshortened

• Narrow 2D sector width to include entire LV and myocardium, and base of LA

• FPS should be between 40 – 90 or at least 40% of HR.

• Initiate breathing techniques

• Acquire 3 cardiac cycles
Activate the Program

Select Measure to activate AFI program.
Define the View

Define ApLAx, 4Ch & 2Ch views for processing.
Anchor 3 Points

Anchor 3 points in the LV, apex and annular hinge points.
Process the Data

Allow the system to process the data.
Read the Reliability of the Fit

System reports the reliability of the data
Set AV Closure (ApLAx)

Adjust aortic valve closure
Longitudinal Strain

Normal Subject

Parametric image

Strain graph

Anatomical M-mode
Normal Subject

Longitudinal Strain Rate from Apical 4-Chamber
Normal Subject

Longitudinal Velocity from Apical 4-Chamber

ATTENTION! Values are averages over segments!
Peak Systolic Strain

GLPSS_LAX: -7.7 %
GLPSS_A4C: -12.4 %
GLPSS_A2C: -14.8 %
GLPSS_Avg: -11.6 %
AVC_CALC: 0.366 sec
Longitudinal Strain

Dilated Cardiomyopathy
Caveats of Speckle-Tracking derived Strain

- **Not angle-dependent**
- **Highly dependent on image quality and acquisition.** (ie: reverberation, attenuation artifacts, etc)
- **Excessive or limited region-of-interest width**
- **Technical proficiency for measurements.**
Attempting to define normal ranges for 2D-based speckle-tracking strain
Myocardial Strain Measurement With 2-Dimensional Speckle-Tracking Echocardiography

Definition of Normal Range

Thomas H. Marwick, MD,* Rodel L. Leano, BS,* Joseph Brown, BS,* Jing-Ping Sun, MD,†
Rainer Hoffmann, MD,‡ Peter Lysyansky, PhD,§ Michael Becker MD,‡
James D. Thomas, MD†

Brisbane, Australia; Cleveland, Ohio; Aachen, Germany; and Haifa, Israel

The interpretation of wall motion is an important component of echocardiography but remains a source of variation between observers. It has been believed that automated quantification of left ventricular (LV) systolic function by measurement of LV systolic strain from speckle-tracking echocardiography might be helpful. This multicenter study of nearly 250 volunteers without evidence of cardiovascular disease showed an average LV peak systolic strain of $-18.6 \pm 0.1\%$. Although strain was influenced by weight, blood pressure, and heart rate, these features accounted for only 16% of variance. However, there was significant segmental variation of regional strain to necessitate the use of site-specific normal ranges. (J Am Coll Cardiol Img 2009;2:80–4) © 2009 by the American College of Cardiology Foundation
<table>
<thead>
<tr>
<th></th>
<th>All Levels</th>
<th>Apical</th>
<th>Mid</th>
<th>Basal</th>
<th>p Value (Levels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All walls</td>
<td>-18.6 ± 5.1</td>
<td>-20.2 ± 5.6</td>
<td>-18.7 ± 3.8</td>
<td>-17.0 ± 5.2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Anterior</td>
<td>‘-19.5 ± 4.2</td>
<td>-19.4 ± 5.4</td>
<td>-18.8 ± 3.4</td>
<td>-20.1 ± 4.0</td>
<td>0.001</td>
</tr>
<tr>
<td>Anteroseptal</td>
<td>-18.8 ± 4.2</td>
<td>-18.8 ± 5.9</td>
<td>-19.4 ± 3.2</td>
<td>-18.3 ± 3.5</td>
<td>0.001</td>
</tr>
<tr>
<td>Inferior</td>
<td>-20.0 ± 4.5*</td>
<td>-22.5 ± 4.5</td>
<td>-20.4 ± 3.5</td>
<td>-17.1 ± 3.9</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Lateral</td>
<td>-18.3 ± 4.7</td>
<td>-19.2 ± 5.4</td>
<td>-18.1 ± 3.5</td>
<td>-17.8 ± 5.0</td>
<td>0.06</td>
</tr>
<tr>
<td>Posterior</td>
<td>-16.3 ± 6.3†</td>
<td>-17.7 ± 6.0</td>
<td>-16.8 ± 5.0</td>
<td>-14.6 ± 7.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Septal</td>
<td>-18.3 ± 5.3</td>
<td>-22.3 ± 4.8</td>
<td>-18.7 ± 3.0</td>
<td>-13.7 ± 4.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>p (walls)</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
</tbody>
</table>

*Inferior was significantly different from all other walls (p < 0.001 except anterior p = 0.02), in the comparison of walls at all levels. †Posterior was significantly different from all other walls (p < 0.0001). In the comparison of levels in all walls, each level was significantly different (p < 0.0001). LV = left ventricular; TQ = tracking quality.
Why is Strain Clinically Important and When to Consider its use?
Strain Imaging for Subclinical Cardiomyopathy

Also Inside —
- Women and Ischemic Heart Disease
- Color M-Mode Echo and Diastolic Dysfunction
- MRI and CT Angiography for Coronary Stenosis
- mIBG for Predicting Atrial Fibrillation
1. General population
Objectives

• Compare GLS with ejection fraction and WMSI for the prediction of mortality
Methods

• 546 consecutive patients (known or suspected LV impairment), 91 died at 5.2 +/-1.5 years

• Simpson's biplane EF and WMSI by 2 experienced readers

• Global longitudinal strain (GLS) was calculated in 3 views using 2D Speckle tracking (18 segments)

• The incremental value of EF/WMSI and GLS to significant clinical variables was assessed using a nested Cox model

Results

- **Mean EF = 58 +/- 12% (16-81%)**
- **WMSI = 1.3 +/- 0.4**
- **GLS = -16.6 +/- 4.3 %**

Conclusions

- GLS is a superior predictor of outcome to either EF or WMSI.
- It may become the optimal method of assessment of global LV function.
- A GLS ≥ -12% was found to be equivalent to an EF ≤ 35% for the prediction of prognosis.
- Use of this threshold could possibly improve access to potentially lifesaving treatments such as implantable defibrillators.

2. Heart failure
Global 2-Dimensional Strain as a New Prognosticator in Patients With Heart Failure

Goo-Yeong Cho, MD, PhD,* Thomas H. Marwick, MD, PhD,† Hyun-Sook Kim, MD, PhD,‡ Min-Kyu Kim, MD,‡ Kyung-Soon Hong, MD, PhD,‡ Dong-Jin Oh, MD, PhD‡
Seoul, South Korea; and Brisbane, Queensland, Australia

Objectives
We sought to evaluate whether global 2-dimensional (2D) strain offers additional benefit over left ventricular ejection fraction (LVEF) to predict clinical events in heart failure.

Background
Although 2D strain based on speckle tracking has been proposed as a simple and reproducible tool to detect systolic dysfunction, the relationship of 2D strain and prognosis has not been studied.

Methods
Two hundred one patients (age 63 ± 11 years, 34% female, LVEF 34 ± 13%) hospitalized for acute heart failure underwent clinical evaluation and conventional and tissue Doppler echocardiography. Using dedicated software, we measured the global longitudinal strain (GLS) in apical 4- and 2-chamber views and the global circumferential strain (GCS) in a parasternal short-axis view. Cardiac events were defined as readmission for heart failure or cardiac death.

Results
There were 23.4% clinical events during 39 ± 17 months of follow-up. In univariate analysis, age, left atrial volume, left ventricular volume, LVEF, ratio of early transmitral flow to early diastolic annular velocity (E/e′), and both GLS and GCS were predictive of cardiac events. In multivariate Cox models, age (hazard ratio [HR]: 1.06, 95% confidence interval [CI]: 1.01 to 1.10, p = 0.017) and GCS (HR: 1.15, 95% CI: 1.04 to 1.28; p = 0.006) were independently associated with cardiac events. By Cox proportional hazards model, the addition of GCS markedly improved the prognostic utility of a model containing ejection fraction, E/e′, and GLS.

Conclusions
GCS is a powerful predictor of cardiac events and appears to be a better parameter than ejection fraction in patients with acute heart failure. (J Am Coll Cardiol 2009;54:618-24) © 2009 by the American College of Cardiology Foundation
Figure 3  Prognostic Value of Echocardiographic Parameters

Incremental prognostic value of the risk factors (ratio of early transmitral flow to early diastolic annular velocity [E/e’], left ventricular ejection fraction, GLS, and GCS) by Cox proportional hazards model presented as a global chi-square value. The addition of GCS resulted in significant incremental improvement in the predictive value on the E/e’, ejection fraction (EF), and GLS. Abbreviations as in Figure 1.
Prognosis Prediction in Patients with Acute Heart Failure

Cho GY, JACC 2009;54:618
3. Evaluation of Myocardial Ischemia
### Strain in Myocardial Ischemia

**Table 2: Studies assessing strain and twist in CAD**

<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects (n)</th>
<th>Purpose</th>
<th>Principal observations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resting echocardiography</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choi et al (2009)</td>
<td>CAD (66), controls (30)</td>
<td>Assessment of LS in CAD</td>
<td>LS correlated with the degree of coronary artery stenosis</td>
</tr>
<tr>
<td>Liang et al (2009)</td>
<td>CAD (39), controls (15)</td>
<td>Assessment of LS in CAD</td>
<td>Decreased LS in ischemic segments</td>
</tr>
<tr>
<td><strong>Stress echocardiography</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bansal et al (2008)</td>
<td>MI (44), no MI (41)</td>
<td>LV rotation with DSE</td>
<td>LV rotation reduced in infarcted segments but not in ischemic segments</td>
</tr>
<tr>
<td>Chan et al (2008)</td>
<td>MI (80)</td>
<td>Transmurality of MI by DSE and CE-MRI</td>
<td>Transmural infarcts showed lower CS, but similar LS and RS as subendocardial infarcts</td>
</tr>
<tr>
<td>Hanekom et al (2007)</td>
<td>CAD (150)</td>
<td>STE and DTI compared during DSE</td>
<td>Correlation better in anterior than posterior circulation</td>
</tr>
<tr>
<td>Ishii et al (2009)</td>
<td>Stable angina (162)</td>
<td>Assessment of LS during stress test</td>
<td>LS detected CAD with 97% sensitivity and 93% specificity</td>
</tr>
<tr>
<td><strong>MI/chronic CAD/ICM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Becker et al (2006)</td>
<td>MI (47)</td>
<td>Transmurality of MI, STE vs CE-MRI</td>
<td>RS had 70% sensitivity and 71% specificity in identifying non-transmural MI</td>
</tr>
<tr>
<td>Bertini et al (2009)</td>
<td>MI (50), ICM (49), non-ICM (38), controls (28)</td>
<td>Evaluation of LV twist</td>
<td>Reduced twist in all patient populations correlated with LV systolic function</td>
</tr>
<tr>
<td>Chen et al (2007)</td>
<td>MI (20), controls (15)</td>
<td>LV strain in MI</td>
<td>Reduced LS in comparison with controls</td>
</tr>
<tr>
<td>Gjesdal et al (2007)</td>
<td>MI (38), controls (15)</td>
<td>Comparison with CE-MRI</td>
<td>LS had 83% sensitivity and 93% specificity in identifying MI</td>
</tr>
<tr>
<td>Delgado et al (2008)</td>
<td>STEMI (99), ICM (123), controls (20)</td>
<td>LS compared with LV EF</td>
<td>LS correlated with LV EF</td>
</tr>
<tr>
<td>Juncut et al (2008)</td>
<td>MI (32), controls (20)</td>
<td>Comparison with CE-MRI</td>
<td>LS had 91% sensitivity and 90% specificity in identifying MI</td>
</tr>
<tr>
<td>Park et al (2008)</td>
<td>No remodeling (28), remodeling (22)</td>
<td>Prediction of remodeling following revascularization</td>
<td>LS independently predicted LV remodeling</td>
</tr>
<tr>
<td>Roes et al (2008)</td>
<td>CAD (80)</td>
<td>Comparison with CE-MRI</td>
<td>LS discriminated transmural from non-transmural scar</td>
</tr>
<tr>
<td>Takeuchi et al (2007)</td>
<td>MI (30), controls (15)</td>
<td>LV twist in MI</td>
<td>CS and twisting velocity was reduced in patients with low EF</td>
</tr>
<tr>
<td><strong>Revascularization/medical therapy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blondheim et al (2007)</td>
<td>ICM (21)</td>
<td>Effects of medical therapy (sensitivity, 70%; specificity, 85%)</td>
<td>Improvement in segmental LS</td>
</tr>
<tr>
<td>Bertini et al (2009)</td>
<td>MI (157)</td>
<td>Comparison with door-to-balloon times and DOCA</td>
<td>Reduced LS correlated with cTnT and door-to-balloon times</td>
</tr>
<tr>
<td>Park et al (2008)</td>
<td>No remodeling (28), remodeling (22)</td>
<td>LS in AMI following revascularization</td>
<td>LS independently predicted LV remodeling</td>
</tr>
<tr>
<td>Han et al (2008)</td>
<td>MI (35), controls (32)</td>
<td>Twist in MI following revascularization</td>
<td>Improvement in twist following revascularization</td>
</tr>
<tr>
<td>Hoffmann et al (2008)</td>
<td>MI (59)</td>
<td>Effect of revascularization, STE compared with CE-MRI</td>
<td>Peak systolic RS predicted functional recovery</td>
</tr>
</tbody>
</table>

AMI: Acute myocardial infarction; CAD: coronary artery disease; CE-MRI: cardiac MRI; CS: circumferential strain; cTnT: cardiac troponin T; DSE: dobutamine stress echocardiography; EF: ejection fraction; ICM: ischemic cardiomyopathy; LS, longitudinal strain; MI, myocardial infarction; RS, radial strain; STEMI, ST-elevation myocardial infarction.
Strain in Myocardial Disease

• Importance of Longitudinal Strain
  – Longitudinal fibers are predominant in the subendocardial region
  – Most vulnerable component of LV mechanics and therefore most sensitive to the presence of myocardial disease.

Geyer H et al. JASE 2010;23:351-69
Strain Imaging During DSE

Strain Imaging During DSE
Post-Systolic Shortening in Ischemia

Normal

Ischemic

SRI M-mode / Curved M-mode

PSS Lasts Longer Than Strain Decrease

Courtesy of Dr Ishii and Nakatani
4. Early detection of cardiotoxicity from chemotherapy
Use of myocardial deformation imaging to detect preclinical myocardial dysfunction before conventional measures in patients undergoing breast cancer treatment with trastuzumab

James L. Hare, MBBS, a Joseph K. Brown, BSc, a Rodel Leano, BSc, a Carly Jenkins, MSc, a Natasha Woodward, MBBS, b and Thomas H. Marwick, MBBS, PhD a Brisbane, Australia

Background Trastuzumab prolongs survival in patients with human epidermal growth factor receptor type 2-positive breast cancer. Sequential left ventricular (LV) ejection fraction (EF) assessment has been mandated to detect myocardial dysfunction because of the risk of heart failure with this treatment. Myocardial deformation imaging is a sensitive means of detecting LV dysfunction, but this technique has not been evaluated in patients treated with trastuzumab. The aim of this study was to investigate whether changes in tissue deformation, assessed by myocardial strain and strain rate (SR), are able to identify LV dysfunction earlier than conventional echocardiographic measures in patients treated with trastuzumab.

Methods Sequential echocardiograms (n = 152) were performed in 35 female patients (51 ± 8 years) undergoing trastuzumab therapy for human epidermal growth factor receptor type 2-positive breast cancer. Left ventricular EF was measured by 2- and 3-dimensional (2D and 3D) echocardiography, and myocardial deformation was assessed using tissue Doppler imaging and 2D-based (speckle-tracking) strain and SR. Change over time was compared every 3 months between baseline and 12 months.

Results There was no myocardial dyssynchrony. SD-EF, SR-EF, and SR were similar. Early decreases in strain and SR were seen in the LV posterior wall and septum.

Conclusions Myocardial deformation identifies preclinical myocardial dysfunction earlier than conventional measures in women undergoing treatment with trastuzumab for breast cancer. (Am Heart J 2009;158:294-301.)
3D LVEF vs. Longitudinal Strain Rate

Hare JL et al. Am Heart J. 2009;158(2):294-301
Early Detection and Prediction of Cardiotoxicity in Chemotherapy-Treated Patients

- **Objectives:** To evaluate if more sensitive echocardiographic measurements and biomarkers could predict later cardiac dysfunction in chemo-treated patients

Slides courtesy of Dr. Plana. AJC, in press.
# Univariate Analysis of Predictors of Cardiotoxicity

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cardiotoxicity</th>
<th>P value (prediction of Cardiotoxicity)</th>
<th>OR</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No (N=34)</td>
<td>Yes (N=9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in left ventricular ejection fraction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 3 months (%)</td>
<td>1.2 ± 9</td>
<td>5.6 ± 8</td>
<td>0.19</td>
<td>5.5</td>
</tr>
<tr>
<td>Change in longitudinal strain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 3 months (%)</td>
<td>3 ± 10</td>
<td>15 ± 8</td>
<td>0.01</td>
<td>500</td>
</tr>
<tr>
<td>Change in radial strain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 3 months (%)</td>
<td>2 ± 23</td>
<td>22 ± 22</td>
<td>0.02</td>
<td>250</td>
</tr>
<tr>
<td>Change in N-terminal pro B type natriuretic peptide at 3 months (%)</td>
<td>46 ± 240</td>
<td>56 ± 190</td>
<td>0.91</td>
<td>1</td>
</tr>
<tr>
<td>Elevation high sensitivity cardiac Troponin I at 3 months</td>
<td>6 (18%)</td>
<td>6 (67%)</td>
<td>0.006</td>
<td>9</td>
</tr>
</tbody>
</table>

Slides courtesy of Dr. Plana.
AJC, in press.
Univariate Analysis of Cardiotoxicity - Diastolic Indices

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cardiotoxicity</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>Yes</td>
<td>P Value</td>
<td>OR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(N=34)</td>
<td>(N=9)</td>
<td>Prediction of Cardiotoxicity</td>
<td></td>
</tr>
<tr>
<td>ΔLAD at 3 months, mm</td>
<td>0.01 ± 0.12</td>
<td>0.05 ± 0.11</td>
<td>0.19</td>
<td>0.01</td>
<td>8.68x10^{-6} – 6.90</td>
</tr>
<tr>
<td>ΔE, at 3 months, %</td>
<td>5 ± 20</td>
<td>1 ± 21</td>
<td>0.47</td>
<td>4.57</td>
<td>0.12 – 201.2</td>
</tr>
<tr>
<td>ΔE/A at 3 months, %</td>
<td>2 ± 24</td>
<td>10 ± 41</td>
<td>0.28</td>
<td>4.05</td>
<td>0.31 – 61.47</td>
</tr>
<tr>
<td>ΔE’ at 3 months, %</td>
<td>6 ± 16</td>
<td>7 ± 17</td>
<td>0.80</td>
<td>0.53</td>
<td>0.003 – 7.59</td>
</tr>
<tr>
<td>ΔE/E’ at 3 months, %</td>
<td>3 ± 25</td>
<td>15 ± 31</td>
<td>0.25</td>
<td>0.17</td>
<td>0.007 – 3.39</td>
</tr>
</tbody>
</table>

Slides courtesy of Dr. Plana.
AJC, in press.
### Sensitivity, Specificity, Positive and Negative Value of the Predictors of Cardiotoxicity

<table>
<thead>
<tr>
<th>Condition</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% decrease long strain</td>
<td>7/9 (78%)</td>
<td>27/34 (79%)</td>
<td>7/14 (50%)</td>
<td>27/29 (93%)</td>
</tr>
<tr>
<td>Increased cTnl at 3 months</td>
<td>6/9 (67%)</td>
<td>28/34 (82%)</td>
<td>6/12 (50%)</td>
<td>28/31 (90%)</td>
</tr>
<tr>
<td>10% decrease long strain and increased cTnl at 3 months</td>
<td>5/9 (55%)</td>
<td>33/34 (97%)</td>
<td>5/6 (83%)</td>
<td>33/37 (89%)</td>
</tr>
<tr>
<td>10% decrease long strain or increased cTnl at 3 months</td>
<td>8/9 (89%)</td>
<td>22/34 (65%)</td>
<td>8/20 (40%)</td>
<td>22/23 (97%)</td>
</tr>
</tbody>
</table>

Slides courtesy of Dr. Plana.
AJC, *in press.*
Other Clinical Applications of Strain

• Aiding in the identification of Myocardial Dyssynchrony

• Regional and Global Function of other cardiac chambers (ie: LA, RV).

• Correlation of regional function and myocardial fibrosis in cardiomyopathies. (ie: amyloid, HCM, DCM, etc)

Geyer H et al. JASE 2010;23:351-69
What’s coming up in the near future?
3D Speckle-Tracking

Single 3D Data Set

Circumferential

Longitudinal

Radial
Layer Specific Strain

Subendocardium  Subepicardium  Whole layer
Strain and Strain Rate

- Free from Translation and Tethering
- Highly dependent on image quality
- It can quantify global and regional myocardial function, adding incremental value to standard measurements.
- Sensitive marker of functional change, ie: early detection of subclinical abnormality → early intervention
Thanks!!